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ABSTRACT

The reality of classroom practices raises a question worth investigation: Are there programs that do not rely on the use of manipulatives that might provide successful mathematics instruction? This paper investigated achievement differences between students in three mathematics programs ranging from a strict manipulative focus to an abstract, non-manipulative approach. The programs incorporated were Explorations by Addison Wesley (the most manipulative in focus), Silver Burdett's Mathematics (a traditional program with several manipulatives suggested), and Comprehensive School Mathematics Program (CSMP, a non-traditional program with a emphasis on non-verbal languages). Pre-testing was in October; post-testing was in spring. Data from teacher questionnaires and formal interviews were collected. The results of the Analysis of Covariance (ANCOVA) revealed that the CSMP was significantly more effective than others. The CSMP was able to hold students at their previous performance level or move them to a higher level. There was no correlation between students' mathematics achievement and teacher experience. Teachers involved with the Explorations program detailed difficulties in classroom management, extensive amounts of time spent making materials and the necessity for longer mathematics sessions. (YP)

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MANIPULATIVE MATERIALS IN THE PRIMARY LEVEL MATHEMATICS LESSON: ARE THERE VIABLE ALTERNATIVES?

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Paper presented at the annual convention of the American Education Research Association, Boston, April 1990

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THEORETICAL FRAMEWORK

The use of manipulatives in mathematics lessons at the elementary school level has been identified as a critical component by researchers for many years (Driscoll, 1981; Hardgrove & Sueltz, 1960; Herbert, 1985; NCTM, 1989; Suydam & Higgins, 1976). Yet, either due to financial factors, time and management concerns or teachers who have not been properly educated in teaching mathematics with manipulatives the materials are rarely used (Gilbert & Bush, 1988; Post, 1980). Fey (1979) reports 9 percent of the teachers on the elementary level never use manipulatives and an additional 37 percent incorporate them in their lessons less than once a week. In a more recent investigation, Gilbert and Bush (1988) concur with Fey's results in identifying from 40.8 to 74.7 percent of the teachers in their study who never or seldom used a variety of suggested manipulatives. Furthermore, the study revealed 47% of the teachers did not believe additional time should be allocated to using manipulatives, leading the researchers to conclude that an increase in the use of manipulatives was not likely. In a research study by Suydam (1984), teachers expressed agreement with the importance of the use of manipulatives but they infrequently employed them in mathematics sessions. These findings suggest that the previous research studies have not been translated well into classroom practice.

The reality of classroom practices raises a question worth investigation:

Are there programs that do not rely heavily on the use of manipulatives that might provide successful mathematics instruction?

OBJECTIVES

The purpose of this study was to document the student achievement differences between three mathematics programs ranging from a strict manipulative focus to an abstract, non-manipulative approach.

OVERVIEW OF THE RESEARCH PROJECT

The study was conducted in the 1988-1989 school year in a Long Island, New York public school system. The district is largely comprised of students from white, middle income families. Approximately 88% of the student population goes on to a higher degree of education. Within the past three years, the district's system of tracking students by ability levels has been completely eliminated. Students at the elementary level, therefore, are placed heterogeneously in classrooms through input of both teachers and the principal. An effort is made to mix an equal number of children at the various ability levels as well as evenly distributing students with special needs such as the learning disabled or the second language learner.

The teachers in the study had an average of 16.3 years of experience in teaching elementary school mathematics with a range of 1-33 years. In an more specific examination of their experience at the just the first grade level, there was a mean of 10.4 years of teaching experience with a range of 1-30 years. The average class size was 21 students and as stated previously they were grouped heterogeneously. Approximately 82% of the teachers taught mathematics for 30-45 minutes per day with the remaining 18% reporting daily mathematics periods of between 46-60 minutes.

In the five district elementary schools, three mathematics programs were implemented on the first grade level in a pilot study. The programs incorporated were Explorations by Addison Wesley (the most manipulative in focus), Silver Burdett's Mathematics (a traditional program with several manipulatives suggested) and Comprehensive School Mathematics Program hereafter referred to as CSMP (a non-traditional program with a emphasis on non-verbal languages). Detailed descriptions of each program in order from the one incorporating the most manipulatives to the program which includes no manipulatives will be given in the following three paragraphs:

Explorations by Addison Wesley is a kindergarten through second grade activity based program. An extension of the process orientation suggested in Mathematics Their Way (Baratta-Lorton, 1976), the focus is on hands-on experiences as a conceptual foundation for mathematics learning. Concepts such as problem solving, number, measurement, operations and geometry are developed through the manipulation of concrete materials and planned interactions with the environment.

The Silver Burdett Program can best be described as having a classical textbook orientation. Their curriculum has been recently updated and includes a focus on problem solving, computational skills and concepts in a real-world context. There is an abundance of traditional "paper and pencil" practice exercises in the students' textbooks. Manipulatives are suggested in the teacher's edition, can be purchased a supplemental kits and are frequently pictured in the worksheets provided for reinforcement.

The CSMP program developed by CEMREL emphasizes conceptual understanding

and applications rather than computational skill development. The curriculum focuses on classification, number theory and elementary logic through the use of representational languages such as String Games (Venn diagram-like activities), Arrows (relationship defining), Storytelling Problems, and the Papy Minicomputer (a positional abacus-like board). The content is sequenced in a spiral organization where concepts are revisited continuously throughout the program. Each revisiting is planned to be at a deeper and more complex level. Prospective CSMP teachers are encouraged to take workshops consisting of 1-5 days of intensive training. The program is constructed so that the lessons are scripted for the teachers and exact wording for teacher-student interactions is encouraged. Such structuring can potentially act as a control within this program for the pedagogical variables.

Each of the five elementary schools had the opportunity to sample all three possible selections. Within the schools, the eighteen teachers were randomly assigned the pilot programs on a voluntary basis. This process resulted in eight teachers working with the CSMP materials (157 students in the cohort), five teachers implementing the Explorations program (88 students in the cohort) and five teachers using the Silver Burdett resources (99 students in the cohort).

METHODOLOGY

The investigation included a quasi-experimental design (Cook & Campbell, 1979) using pre-test and post-test data on student achievement, teacher questionnaires, and in-depth interviews with teachers and administrators. Prior to the beginning of the year,

workshops on each of the programs were presented to prepare the teachers for the pilot study.

The CSMP workshops were held for two days just before the first day of school. Lead by a local consultant who has had extensive training through the CEMREL organization, the teachers were given a general overview of the teaching strategies incorporated in the use of each of the non-verbal languages. Workshops related to Explorations and the Silver Burdett program were given by representatives of the companies as well as additional follow-up sessions highlighting the use of manipulatives which were conducted by the district's Elementary Mathematics Enrichment Teacher.

During the fall, provisions were made for all interested teachers (particularly those piloting the CSMP program) to make visitations to other school districts where CSMP has been implemented for several years. Teachers sat in on math classes and were given suggestions regarding the use of supplemental reinforcement materials. In addition, teachers in all programs were encouraged to visit one another's mathematics periods to get a first-hand experience with each of the piloted programs. A pre-test and a post-test were developed by the researcher in conjunction with the district's mathematics enrichment specialist. During test development, the tests were reviewed by an external committee of mathematics professors and educational practitioners. The tests were based on the information appropriate for first graders as designated in the New York State Mathematics Syllabus and stressed concepts and problem solving rather than computational skills. Careful attention was given to balancing out the items so that no one program would be advantaged or disadvantaged. Specific CSMP language and

content (minicomputer, etc.) were consciously avoided to be equitable.

The pre-test was administered by the individual classroom teachers in October within a timeframe that provided a one day window. Whereas, the post-test was administered on two days in the spring of 1989 by either the researcher or a trained staff which included student teachers and principals. In an effort to standardize the process, at each test administration the administrator was given a protocol to follow.

The teacher questionnaires were completed during a First Grade Level Meeting. The instrument requested information on their pilot program, age, sex, years of overall teaching experience, years of first grade teaching experience, approximate level of their class's math ability, and time spent teaching mathematics. The second page of the survey was a modified version of the 1976 Dutton Attitude Toward Mathematics Scale (Form C, Scale 5).

Formal interviews were conducted with a total of seven teachers and one administrator with representation from all of the elementary schools in the district. Interviews were conducted during the months of March and April with some follow-up contacts in the month of May. The teachers were selected randomly (within program) with an effort to connect with approximately one-third of the teachers in each of the three piloted programs. Therefore, three teachers using CSMP, two using Explorations and two using Silver Burdett were interviewed for an average of 45 minutes. A formal interview schedule was incorporated at each appointment to allow for a comparative examination of responses. In addition, one of the building principals who played an active role on the district-wide mathematics committee volunteered to be interviewed

on his perceptions regarding the implementation of all three programs in his building.

An analysis of covariance was conducted by program (covarying out the results from the pre-test) to evaluate the residual gain scores. This method was used so that initial differences in student cohorts could be controlled as well as providing a means to assess whether the students performed above or below the predicted score. The average of the residual scores, for all the students in a particular program, has then been considered as one measure of the program's effectiveness.

A test for homogeneity of regression was conducted prior to this analysis, to assess the validity of the assumption that in the process of adjusting for the covariate the b weights (common regression coefficients) for the regression are not significantly different. The examination of the proportion of variance accounted for using separate regression coefficients as compared to the proportion of variance accounted for by using common regression coefficients indicated that there was no significant difference (R square change=.00379). Therefore, the assumptions underlying the analysis of covariance were established as valid in this case suggesting such an analysis would be appropriate.

FINDINGS

The results of the analysis of covariance revealed that the CSMP program was significantly different (p less than .01). Although the visual examination of the final achievement scores did not appear dramatically higher, the CSMP cohort initially measured at a low level and therefore showed greater growth. A post hoc analysis was performed to determine the "honestly significant differences" or precisely what programs

within the equation were different from CSMP. As examined in three independent tests (Scheffe, Tukey and Student-Newman-Keuls), the differences identified were specifically between the CSMP and the Explorations program.

The following table shows the means on the post-test which have been adjusted for the results of the pre-test. Therefore, these means better represent the final student achievement.

ADJUSTED MEANS FOR POST-TEST BY PROGRAM

Program	Adjusted Mean
CSMP	22.526 (n=157)
Explorations	21.113 (n= 88)
Silver Burdett	21.733 (n= 99)

The variables of the number of years of teachers' experience and the number of years of teachers' experience at the first grade level were examined to see their impact on the variance. It was thought that possibly the teachers with a greater amount of experience would have students with higher scores regardless of the piloted program. A Pearson Correlation was performed on both the individual raw score (representing years of experience both overall and at first grade) and on two categories based on the extremes of "very experienced teacher" (greater than fifteen years) and "novice teachers" (less than eight years). In each case, the experience variables did not demonstrate an impact on the students' mathematics achievement on the post-test (overall teacher experience .075

and teacher experience at first grade .067). Therefore, these factors were not of further interest.

The following correlation matrix represents the correlations for the individual scores on both levels of teacher experience as they relate to the pre-test and the post-test. It should be noted that there was a significant correlation between the two tests (.5798) indicating that the pre-test can be considered a viable covariate.

PEARSON CORRELATION COEFFICIENTS

	Pre-Test	Post-Test	Total Exper.	Grade Exper.
Pre-Test	1.0000	.5798	-.0062	-.0521
Post-Test		1.0000	.0752	.0667
Total Exper.			1.0000	.7466
Grade Exper.				1.0000

In an effort to assess the programs' success within student subgroups (low, middle and high achieving), a Crosstabs matrix was generated to inspect the end of the year changes. The subdivisions were based on divisions generated from the means and standard deviations of each test. The low group was defined as those students scoring

less than one standard deviation below the mean on the test. Students in the middle group were those who had scores falling between one standard deviation above or below the mean. The students designated in the high category received a score over one standard deviation above the mean.

For the low performing students, as measured on the pre-test, the CSMP program moved the greatest percent of these students to the middle and high functioning range on the post-test. In the middle-range scores on the pre-test, the CSMP program most successfully kept the students at the middle range or moved them to the highest grouping. At the range of the highest functioning students, CSMP and Silver Burdett were comparable in their success at keeping the students in the highest level on the post-test. In conclusion, the one program that was able to hold students at their previous performance level or move them most successfully to a higher achievement level was CSMP. The following Table indicates the percentages of students in each performance category and their movement by program on the post-test:

STUDENT PERCENTAGES ON POST-TEST BY PERFORMANCE CATEGORY ON PRE-TEST (ACCORDING TO PROGRAM)

(n in parentheses)

Low Pre-Test Students

	Stayed Low	Moved to Middle	Moved to High
CSMP	31.3% (10)	65.6% (21)	3.1% (1)
Explorations	56.5% (13)	39.1% (9)	4.3% (1)
Silver Bur.	50.0% (7)	50.0% (7)	0

Middle pre-Test Students

	Moved to Low	Stayed Middle	Moved to High
CSMP	12.1% (12)	70.7% (70)	17.2% (17)
Explorations	13.3% (6)	80.0% (36)	6.7% (3)
Silver Bur.	13.1% (8)	73.8% (45)	13.1% (8)

High Pre-Test Students

	Moved to Low	Moved to Middle	Stayed High
CSMP	0	46.2% (12)	53.8% (14)
Explorations	0	75.0% (15)	25.0% (5)
Silver Bur.	0	54.2% (13)	45.8% (11)

The interviews with the teachers generated data which described similar problems regarding the use of manipulatives as expressed in previous research. The teachers involved with the Explorations program detailed difficulties in classroom management, extensive amounts of time spent making materials and the necessity for longer mathematics sessions. From the teachers' perspective, the interventions given to all teachers but expressly incorporated to ease the transition to a more manipulative program did not alleviate the management and time concerns.

CONCLUSIONS

The findings of both the statistical analysis and the qualitative data suggest that the programs should be analyzed over a longer period of time. Specifically, it would be suggested that the piloted programs should be repeated in the first grade while the study continues with the present first graders in their second grade experience. In this way, the teachers can better prepare themselves for the non-traditional program, which would more ably control for the differences in the teachers' preparation. This extension would also enable the teachers to gain perspective as the program moves to a different grade level with students of advancing development and with a focus on both additional and more complex mathematical topics. The opting of a two-year model would probably provide the opportunity for teachers to feel more confident in their own decisions after a second year of experience with the materials.

Without additional time to study the programs, the ability of the manipulative programs to demonstrate long term effects would be overlooked. In addition, it would

be dangerous to make a broad generalization from data that only examines performance in the first grade. Although, even in the programs suggesting the greatest use of manipulatives, a shift to abstraction and a de-emphasis on hands-on experiences takes place in the intermediate grades.

The data indicated that a non-traditional, abstract mathematics program may be successful in increasing student achievement at all performance levels in a first grade. This finding might articulate well with cognitive research studies that suggest students are able to learn complex skills without necessarily possessing the putative prerequisite concepts (Siegler, 1986).

In conclusion, this study begins to investigate alternative mathematics programs to the manipulative oriented programs suggested by research but frequently not transformed into classroom practice. Programs like the Comprehensive School Mathematics Program should be examined in greater depth with an attempt to control, where possible, for teacher delivery.

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